Department of the Navy
Bureau of Ordnance
Contract NOrd-16200
Task 4

MODIFICATION AND FLOW CALIBRATION OF TEST SECTION OF HIGH-SPEED WATER TUNNEL

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CALIFORNIA INSTITUTE OF TECHNOLOGY
Pasadena, California

Report No. E-73.10
December 1958

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SUMMARY

The test section of the High-Speed Water Tunnel (1) was modified in preparation for experiments on the force and cavitation characteristics of torpedo fins and control surfaces mounted on a reflection plane. The modification involved installing a reflection plane in the 14-inch diameter working section of the tunnel. The reflection plane is described and the results of flow calibrations of the tunnel test section with the reflection plane installed are given. This report summarizes the work completed under Task 4 of Contract NOrd-16200.

INTRODUCTION

An experimental investigation to determine the effects of cavitation on the forces and moments on torpedo fins and control surfaces was begun in the Hydrodynamics Laboratory in April, 1956. During the period from June, 1956 to April, 1957, the design, fabrication, installation, and calibration of modifications to the test section and model support system of the High-Speed Water Tunnel were carried out. The water tunnel was modified by installing a plane wall within the existing 14-inch diameter section to make possible the testing of large-scale models of torpedo fins and control surfaces.

After completion of the modification and the calibration tests, and before model and hinge moment balance design was completed, the work on this project was interrupted in favor of higher priority test programs. At the request of the Bureau of Ordnance, the funds remaining in this task assignment were expended in studies of the dynamic force and free flight characteristics of the Basic Finner missile.

Subsequent to the calibration experiments, the reflection plane test section was used in studies of the force and cavitation characteristics of three-dimensional hydrofoils under contract Nonr-220(12). This hydrofoil program has provided valuable information on cavitation, pressure distribution, and aspect ratio effects for wedge-shaped and circular-arc hydrofoils which can be applied readily to the design of fins and control surfaces for high-speed torpedoes and underwater missiles.

This report describes the water tunnel modifications and the results of the calibration tests.

TEST SECTION MODIFICATION

The reflection plane setup was installed in the 14-inch diameter test section of the High-Speed Water Tunnel. The reflection plane consisted of a vertical flat plate mounted within the existing test section 3.5 inches from the test section axis. The plate, 12 in. high by 20 in. long, was faired to a simple, circular-arc nozzle casting and a 23 1/4 in. long, 3 1/2 deg. diffuser section. The nozzle casting has a 25 7/16 in. radius circular-arc profile which is hand-faired at its downstream juncture with the flat plate to eliminate the discontinuity in curvature. No fairing was used between the nozzle section and the circular test section wall. The flat diffuser section extended into the water tunnel diffuser and was terminated in an abrupt step. This type of section had proved successful in the two-dimensional water tunnel tests of hydrofoils, and it was felt that attempts to diffuse the flow completely, without separation, would be unsuccessful with such an unsymmetrical flow configuration. With this setup, separation occurred at a fixed and stable position. The reflection plate assembly is shown in Fig. 1. Figure 2 shows a view, looking downstream, of the plate set up in the tunnel test section. The test section window and a hydrofoil model can be seen in this figure.

Five static pressure taps were installed along the horizontal centerline of the flat plate and provision was made for making velocity and pressure surveys across the test section at nine points. A rake with 16 static and total head tubes was used in flow calibration experiments described below.

The fin and control surface models were designed to be mounted on a 5-inch diameter disk attached to the balance spindle and set flush with the reflection plate. A small radial clearance-gap was provided between the spindle disk and the flat plate. A hollow cylindrical spindle, 3 5/16 in. in diameter by 4 inches long, supported the mounting disk. The space around the spindle was sealed from the remainder of the space behind the reflection plane by a pressure shield so that the pressure around the spindle, mounting disk, and force-balance seal was the same as in the test section. The spindle and model can be rotated through 360 degrees.

With this setup, forces would be measured on both the fin model and the spindle disk. In order to determine the tare forces on the spindle disk, it is necessary to repeat force tests with the model mounted on a streamlined image strut supported from the side of the test section opposite from the reflection plane. The image strut was mounted on a brass plate installed in the frame of the test section window, and the angle of attack of the model varied from the outside of the tunnel. The model was mounted on the image strut and it was positioned so that the free base was within approximately 0.002 in. of the spindle disk. In these tests, the forces and moments could be measured on the spindle disk alone and these data applied as corrections to the force and moments measured on the fin-disk combination.

The control-surface hinge-moments were designed to be measured separately with a single component balance inside the spindle of the three-component force balance. The three-component force balance, force gages, and data-recording systems are described in references 2 and 3.

FLOW CALIBRATION TESTS

Flow velocity and pressure calibration tests were made in the reflection plane test section at velocities of 20, 30, 40, and 50 fps. These measurements were made at nine locations in the test section, using a rake containing five static pressure and 11 total head tubes. The velocity profile was uniform over the region tested except for the boundary layers on the flat reflection plane and tunnel wall. The boundary layer on the reflection plane was approximately 3/8 in. thick at the balance spindle centerline. Figure 3 shows the measured velocity profile at the balance spindle location for velocities of 40 and 50 fps.

A static pressure calibration along the flat reflection plane was made simultaneously with the velocity profile measurements. These tests showed a slight decrease in pressure along the length of the test section amounting to a decrease in the pressure coefficient of .006 per foot.

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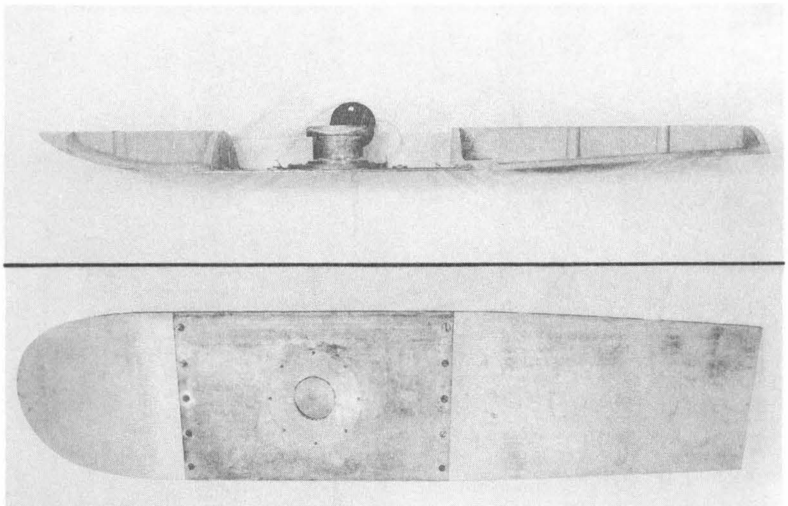

Fig. 1 - Reflection plate, spindle shield, nozzle, and diffuser assembly

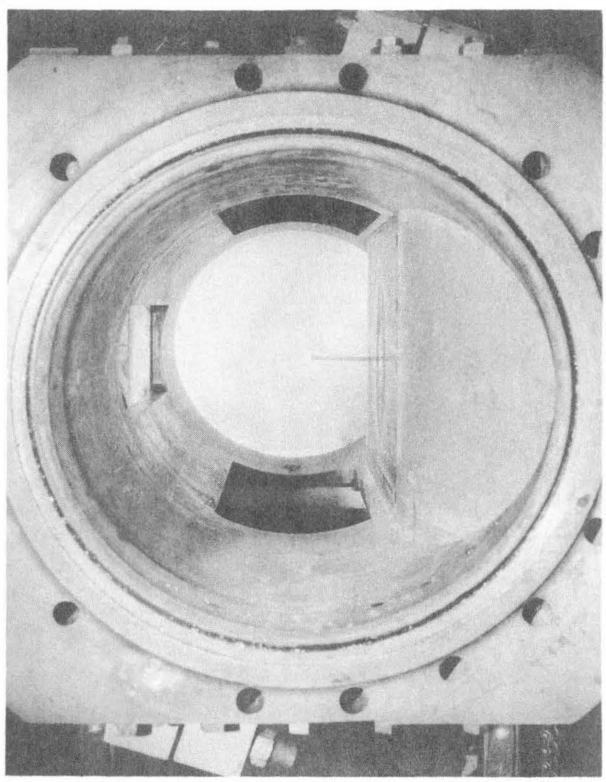

Fig. 2 - View looking downstream in reflection plane test section

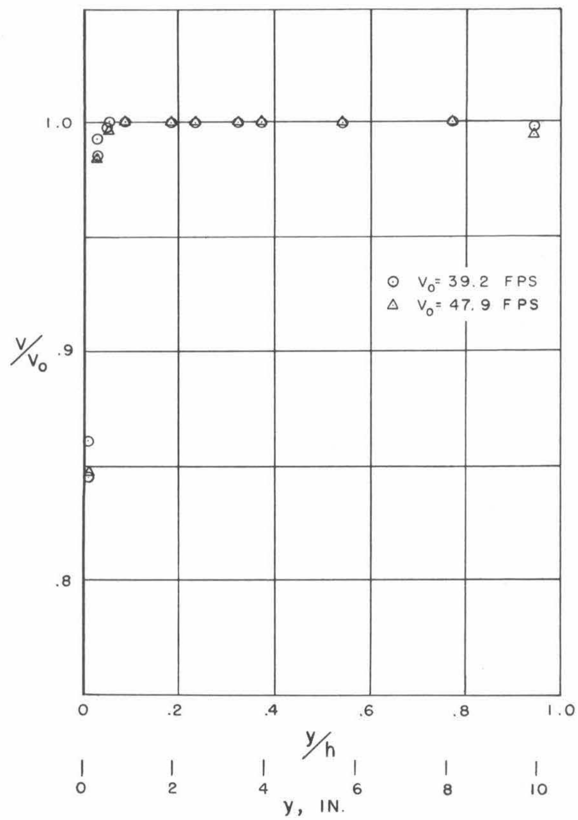

Fig. 3 - Transverse velocity profile at spindle axis